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On hot list chart

EXHIBIT F

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PATENT ABSTRACTS OF JAPAN

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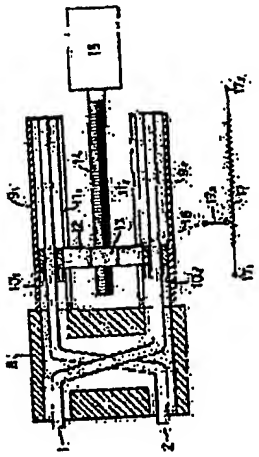
(54) VARIABLE PHASE SHIFTER

(57)Abstract:
PURPOSE: To decrease the input power standing wave ratio and also to increase the variable phase shift quantity by connecting a coaxial guide to two output terminals of a hybrid coupler so as to short-circuit an inner/outer conductor of a coaxial waveguide at an optional position.
CONSTITUTION: The coaxial guides 91, 92 are fitted to two output terminals of the hybrid coupler 8 and the outer guide and the inner conductor of the coaxial guide are short-circuited by short circuit plates 101, 102. Both the short-circuit plates 101, 102 are connected by a connecting plate 12 through slots 111, 112 made to both the coaxial guides 91, 92. A female screw 13 is provided to the connecting plate 12, the connecting plate 12 is forwarded/reversed by the turning of a screw rod 14 screwed to the female screw 13 so as to slide the short- circuit position of both the coaxial guides. The turning of the screw rod is given by a motor 15.



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審査請求 有　発明の数 1　(全4頁)

⑭発明の名称　可変移相器

⑳特　願　昭59-127763
㉒出　願　昭59(1984)6月21日

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明　細　書

1．発明の名称

可変移相器

2．特許請求の範囲

(1)2個の出力端子を有し，そのおのおのに入力信号電力レベルの約1/2ずつで，かつ90度の位相差を有する信号を取り出すハイブリッド結合器の該両出力端子に，それぞれ平行に同軸管を接続し，それら各同軸管の外管に対向して軸に沿う溝を設け，各同軸管の内外導体短絡板を直径線を通した連結板で結び，その連結板の雄ネジに電動機で回転駆動されるネジ棒を螺合すると共に連結板に摺動抵抗器の摺動片を連動させ，この摺動抵抗器の固定端子に一定の電圧を印加しておく構成としたことを特徴とする可変移相器。

3．発明の詳細な説明

(産業上の利用分野)

本発明は連続可変移相器の改良に係るものである。

(従来の技術)

従来，連続的に高周波信号の位相を変化させる移相器として，種々の形式が使用されて来た。伝送線路の長さを連続的に変化させれば目的を達成できるので，初期には第1図のいわゆるU字形ライン・ストレッチャが使用された。

第1図中，1は入力端子，2は出力端子，3_1は入力同軸管の外管，3_2は同内導体，4_1，4_2はそれぞれ出力同軸管の外管と内導体である。これらの先端にU字形の同軸管を挿入し，その外管5_1と内管5_2の先端はそれぞれ入出力同軸管の外管内部および内導体の外部に接触させている。

従って，このU字同軸管をx軸移動させれば，入出力端子1，2間の同軸線路長はその2倍変化させることができるから，使用最低周波数に相当する波長の(1/2)の摺動範囲を持たせれば，0～1波長の位相変化を可能とすることができる。しかしこの方式の欠点はU字同軸管の特性インピーダンスを入出力同軸管と一致させることができない。従って，入力電圧定在波比が悪くかつ大形に

なることである。

そこで、特に小形にする目的から、第2図の如く、ハイブリッド回路とバラクタ・ダイオードを組み合わせたものも使われている。同図はハイブリッド回路の1種であるブランチ・ライン回路6の出力端子6_3、6_4にバラクタ・ダイオード7_1と7_2を接続したものである。

第3図はこの動作原理を説明するもので、今入力端子6_1に単位入力1が入ると、出力端子6_3には$A\,e^{jx}$、出力端子6_4には$jB\,e^{jx}$の出力が現われる。

今両出力端子6_3、6_4に接続されているバラクタ・ダイオードの特性が完全に一致して、その反射係数を共にΓとすると、ダイオードからの反射は$\Gamma A\,e^{jx}$および$j\Gamma B\,e^{jx}$となる。この反射波電力もそれぞれ2分されて端子6_1と端子6_2に現われる。まず、入力端子6_1に出現する出力は、端子6_3からの反射波分（$\Gamma A^2\,e^{j2x}$）と端子6_4からの反射波分（$-\Gamma B^2\,e^{j2x}$）の和即ち$\Gamma(A^2-B^2)\,e^{j2x}$となる。また端子6_2に現われる端子6_3からの反射分は（$j\Gamma AB\,e^{j2x}$）、端子6_4からの反射分も（$j\Gamma AB\,e^{j2x}$）となるので、その合成波は（$-j2\Gamma AB\,e^{j2x}$）となる。

今ハイブリッド内の損失をゼロとすれば（$A^2+B^2=1$）となり、またハイブリッド特性が完全で$A=B=1/\sqrt{2}$とすれば、入力端子6_1（#1）に現われる反射波はゼロとなり、移相器の出力端子6_2（#2）には（1）式の出力波すが現われる。

$$\tau=j\Gamma\,e^{j2x}\quad\cdots\cdots(1)$$

線路の特性インピーダンスをZ_0、信号の各周波数をω、バラクタ・ダイオードの等価静電容量をCとすると、その基準化リアクタンスXは

$$X=-1/(\omega C Z_0)\quad\cdots\cdots(2)$$

となるから、この反射係数Γは

$$\Gamma=\frac{jX-1}{jX+1}=\frac{-1+jX}{1+jX}=\frac{-(1-jX)^2}{1+X}=-1\angle\theta$$

故に$\tan\theta=2X/(X^2-1)$となり、従って、

$$\cos\theta=1/\sqrt{1+\tan^2\theta}=(X^2-1)/(X^2+1)$$

$$\theta=\cos^{-1}\{(X^2-1)/(X^2+1)\}\quad\cdots\cdots(3)$$

故に移相器の出力端子6_2（#2）に現われる信号は、その振幅が入力端子6_1（#1）の入力信号に等しく、位相はバラクタ・ダイオードの等価静電容量Cの変化に伴なって（3）方式のように変化する。

また、3dBハイブリッドが完全ならば、入力端子に現われる反射波信号はゼロになり、小形に作れる特徴があるが、バラクタ・ダイオードの静電容量の変化範囲の制限等から、電気角で90度程度が限界となりダイオードの抵抗分のために損失が大きく、その上移相量を90度以上とするためには数段直列に接続する必要があって、特に挿入損失が大きくなる。

〔発明が解決しようとする問題点〕

本発明は上記に鑑みて提案されたもので、入力電力定在波比および挿入損失が小さく、移相量の大きな可変移相器を小形軽量に得ることを目的とする。

〔問題点を解決するための手段〕

本発明は2個の出力端子を有し、そのおのおのに入力信号電力レベルの約半ずつで、かつ90度の位相差を有する信号を取り出すハイブリッド結合器の該両出力端子に、それぞれ平行に同軸管を接続し、それら各同軸管の外管に対向して軸に沿う溝を設け、各同軸管の内外導体短絡板を前記溝を通した連結板で結び、その連結板の雄ネジに電動機で回転駆動されるネジ棒を螺合すると共に該連結板に摺動抵抗器の摺動片を連動させ、この摺動抵抗器の固定端子に一定の電圧を印加する構成とした可変移相器である。

〔作用〕

本発明は上記の構成であるから、電動機でネジ棒を回転させると、連結板が前後進して該連結板で連結した各同軸管の内外導体短絡位置を変化させ、各同軸入力信号の位相を変化させる。また、上記連結板の移動に連動して摺動抵抗器の摺動片が移動し、この摺動片電圧は同軸管短絡板位置と一対一の対応を示すことになる。

そこで、例えば、制御電圧と前記摺動片電圧とを作動増幅器に導き、この出力電圧で前記電動機

を回転させ検出出力電圧が零になったとき電動機の回転を止めるようにして、外部からの制御電圧により各同軸管の内外部体短絡位置、従って、高周波入力信号の位相を変化させるものである。

〔実施例〕

第4図は本発明の実施例説明図である。3dBハイブリッド結合器としては、第2図に示すブランチ・ライン結合器の使用もできるが、より電気的特性の良好な（λ）波長分布結合形ハイブリッド回路8を使用した。これは主線路と副線路を交叉させて結合器の2個の出力端子が同一方向に取り出せるようにする。この出力端子に2個の同軸管9₁、9₂を取り付け、この外管と内導体とは、短絡板10₁、10₂で短絡する。そしてこの両短絡板は、両同軸管に穿たれた溝11₁および11₂を通して連結板12で結ばれている。連結板12には、雄ネジ13が設けられており、このネジ13にねじ込まれたネジ棒14の回転で連結板12が前後進し、両同軸管の短絡位置が移動される。ネジ棒14の回転は電動機15によって与えられる。

一方可変抵抗器17の摺動片17₃は連結機構18によって機械的に連結板12と連結し、同軸管9₁、9₂の短絡位置と連動してその位置が移動する。この可変抵抗器17の固定端子17₁と17₂には適当な直流または交流の電圧が印加されているので、摺動片17₃の電圧は、同軸管短絡位置と一対一の対応を示すことになって前記の如く作用する。

本発明の実施例の動作原理も前記第3図で説明され、(2)式に相当する短絡同軸管9₁、9₂の入力基準化リアクタンスXは、基準点から短絡位置までの長さをℓとして、

$$X=\tan(2\pi\ell/\lambda)=\tan(\omega\ell/Vc) \quad \cdots\cdots(4)$$

となる。式中λは信号の波長、Vcは光速である。

この基準化リアクタンスXを(3)式に代入すれば、移相量が求められるが、長さℓの変化による基準化リアクタンスXの変化範囲は$-\infty$から$+\infty$までとなり得るので、360度の移相も容易にできる。例えば移相量が90度とすれば、（ℓ／λ）の値は0.125でよい。

〔発明の効果〕

以上、本発明の連続可変移相器の特徴を挙げれば、次のようになる。

1．入力電圧定在波比が小さい。ライン・ストレッチャ形では1.5以上となるが、本発明では1.1以内に納め得る。

2．挿入損失が小さい。バラクタ・ダイオード方式ではダイオードの損失のために、一段で最大移相量40度以内でも、0.6～0.7dBの挿入損失を示すが、本発明の移相器では移相量90度以上で挿入損失は0.3dB以下である。

3．移相量が大きい。バラクタ・ダイオード方式では1段当り40度が限界だが、本発明の移相器ではこの制限がない（短絡摺動長を長くすればよい）。

4．小形軽量である。移相量がある程度よりも大きいとき、一段で済むことから、バラクタ・ダイオード方式より反って小形となる。またライン・ストレッチャでは全長が摺動長の2倍以上となるから、本発明の方が小さい。

本発明による可変移相器は、上述の特徴があるためシステムの小型・軽量化、低損失化が強く望まれる各種移動無線通信等への適用が充分に期待できる。

4．図面の簡単な説明

第1図はU字形ライン・ストレッチャを使用した従来の移相器の断面構成図、第2図はバラクタ・ダイオードを使用した移相器の構成図、第3図は同原理説明図、第4図は本発明による可変移相器の概略構造を示す断面図である。

1は入力端子、2は出力端子、3₁、4₁は入出力同軸管外管、3₂、4₂は同内導体、5₁、5₂はU字形ライン・ストレッチャの外管および内導体、6は3dBブランチ・ライン形ハイブリッド回路、6₁、6₂、6₃、6₄はその端子、7₁、7₂はバラクタ・ダイオード、8は3dB分布結合形ハイブリッド回路、9₁、9₂は同軸

管、10₁、10₂は短絡片、11₁、11₂は筒、12は短絡板、13は細ネジ、14はネジ棒、15は電動機、16は機械的連結機構、17は可変抵抗器、17₁、17₂は抵抗器固定端子、17₃は同摺動端子。

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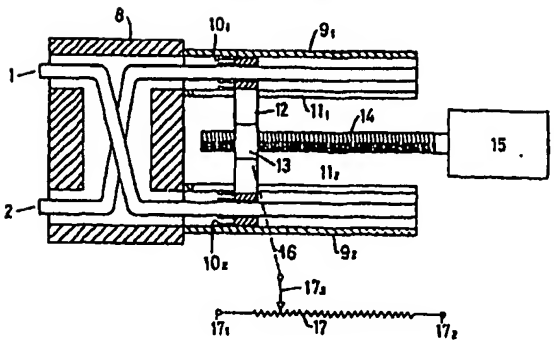
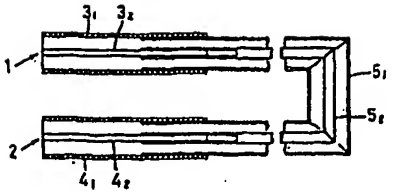
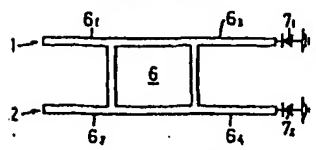
第4図



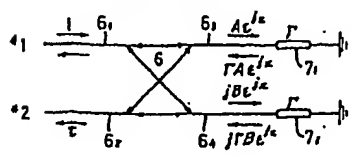
第1図



第2図



第3図



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1. (54)[Name of invention] Variable Phase Shifter

2. [Area of Patent Claims]
The variable phase shifters that has two output terminals incorporated. Connecting the coaxial tubes in parallel to the terminals of Taking out the signals of approximately 1/2 of power level of input signal with 90 degree differential phase of Hybrid Combiner, and connecting inner and outer conducting plates of those coaxial tubes respectively through the connecting plates through structure above, connect the screwed pole connected by the rotator of electric motor to the those female screws of the connecting plates and connecting brush contacts of the variable resistors, and apply fixed voltages to the fixed terminals of the variable resistor for positioning controls. The variable phase shifter has above feature and structure.

3. [Details of the Invention]
[Industrial Application]
This invention is concerning to the improvement of continuous variable phase shifter.

[Current Technology]
Currently, some different kinds of types are used as phase shifter for changing the phases of the signals of the high frequency continuously. Changing the length of the transmitting circuit continuously that will reach to the purpose. At the beginning, the Fig. 1 so called U style Line Stretcher was used. In the Fig. 1, the symbol 1 is input terminal, symbol 2 is output terminal, symbol 3_1 is outer conductor of the coaxial tube, symbol 3_2 is inner conductor of the coaxial tube, 4_1 and 4_2 are same as above of output terminal. Insert each edges of the U style coaxial tubes to the edged of these tubes that contacts each edges of the outer conductor 5_1 and inner conductor 5_2 to the inside of the outer conductor and outside of the inner conductor.

Accordingly, moves X mm U style coaxial tube that will changes the length of the input and output terminals 1 and 2 that will changes the length of the coaxial lines by 2 times larger. So, changes the phase of 0~1 wave can be made when the resistance range equivalent to the (1/2) wave of the applicable lowest frequency. However, negative issue of this U style coaxial tube is that the impedance can not be match with input and output coaxial tubes. Consequently, input voltage standing wave ratio is going to be poor and physical size of the phase shifter is going to be large.

Thus, to the purpose especially down sizing, the combination of the hybrid circuit and the varactor diode as in the Fig. 2 are used. Fig. 2 is the circuit consists by connecting the varactor diodes 7_1 and 7_2 to the output terminals 6_3 and 6_4 of branch line that is a kind of hybrid circuit. **Fig. 3 is equivalent circuit for explanation of working principal. Supply signal 1 into input terminal 6_1, appears $A\varepsilon^{jx}$ at output terminal 6_3 and $jB\varepsilon^{jx}$ at output terminal 6_4.**

Match the characteristic of the varactor diodes connected to the output terminals 6_3 and 6_4 completely, state both of its reflection coeffiecient as Γ, the reflection from diode will be $\Gamma A\varepsilon^{jX}$ and $j\Gamma B\varepsilon^{jx}$. These reflected powers will be appeared with divided by 1/2 on the terminals 6_1 and 6_2. Firstly, the output to be appeared at the input terminal 6_1 will be $\Gamma(A^2 - B^2)\ \varepsilon^{j2X}$ that is sum of reflection ($\Gamma A^2\varepsilon^{j2X}$) from terminal 6_3 and reflection ($-\Gamma B^2\varepsilon^{j2X}$) from terminal 6_4. Also, the reflection from terminal 63 to be appeared at the terminal 62 will be ($j\Gamma AB^2\varepsilon^{j2X}$), from terminal 64 will be ($j\Gamma AB^2\varepsilon^{j2X}$) that sum of vector will be ($j2\Gamma AB^2\varepsilon^{j2X}$).

Supposed loss inside hybrid as zero, it will be ($A^2 + B^2 = 1$). Also, supposed the characteristic of hybrid is perfectly $A = B = 1/\sqrt{2}$, the reflecting wave to be appeared at the input terminal 6_1 (#1) will be zero and following output wave τ will be appeared at the output terminal 6_2 (#2) of phase shifter.

$$\tau = j\Gamma\varepsilon^{j2X} \quad \ldots\ldots\ldots (1)$$

Supposed to state the characteristic impedance of circuit lines as Z_0, respective frequencies of signals as ω, equivalent static capacitance of varactor diode as C, the referenced reactance X will be;

$$X = -1/(\varepsilon C Z_0) \quad \ldots\ldots\ldots (2)$$

The reflection coeffiecient Γ will be;

$$\Gamma = \frac{JX-1}{JX+1} = \frac{-1+jX}{1+jX} = \frac{-(1-jX)^2}{1+X} = -1 < \theta$$

Therefore, $\tan\theta = 2X/(X^2-1)$

Accordingly,

$$\cos\theta = 1\sqrt{1+\tan^2\theta} = (X^2-1)/(X^2+1)$$

$$\theta = \cos^{-1}\{(X^2-1)/(X^2+1)\} \quad \ldots\ldots\ldots (3)$$

Therefore, the signal to be appeared at output terminal 6_2 (#2) of phase shifter will be equal its amplitude to the input signal of input terminal 6_1 (#1), the phase will be changed per formula (3) above in accordance with the changes of the equivalent static capacitance C of varactor diode.

Also, supposed 3 dB hybrid is perfect, the reflecting signal to be appeared at input terminal will be zero that phase shifter can be made by small size. However, electrical tilt approx. 40 degree is limit due to the limitation of the range of the variation of the static capacitance of varactor diode that is large loss due to the resistance of the diode. Moreover, especially input loss will be greater that some series connections are required for controlling phase range higher than 90 degree.

[The Subject of Solving by Invention]
This invention has been submitted for considering to the above matter that the purpose of the variable phase shifter can be low insertion loss, low voltage standing wave ratio, large phase range controls, small size and light weight.

[Solving Method of the Subject]
The variable phase shifters that has two output terminals incorporated. Connecting the coaxial tubes in parallel to the terminals of Taking out the signals of approximately 1/2 of power level of input signal with 90 degree differential phase of Hybrid Combiner, and connecting inner and outer conducting plates of those coaxial tubes respectively through the connecting plates through structure above, connect the screwed pole connected by the rotator of electric motor to the those female screws of the connecting plates and connecting brush contacts of the variable resistors, and apply fixed voltages to the fixed terminals of the variable resistor for positioning controls. The variable phase shifters have above structures.

[Function]
This invention is structured as above. Rotate screw by motor, connecting plate will be actuated to forward or backward that changes positions of the outer and inner conductors of each coaxial tubes that changes the phase of the high frequency input signals. Also, in conjunction with connection of the connecting plate and rotator of the variable resister, moves rotator of the variable resister that voltage at the rotator will indicate response 1:1 to

the position of the short-circuit plate of the coaxial tubes. So, for example, guide the controlled voltage and the voltage of the rotator of the variable resister to the differential amplifier. Then, operate motor mentioned above by the output voltage of the differential amplifier with setting the motor shall stop rotation when output voltage is zero that shall short positions outer and inner conductors of each coaxial tubes, changes the phase of the high frequency input signals accordingly.

[Operation Example]

Fig. 4 is perspective diagram as a example of the invention. The branch Line combiner per Fig. 2 can be used for the 3 dB hybrid combiner, but used rather high electrical performance (1/4) wave length distribution coupling type hybrid circuit 8. This circuit shall cross the main line and sub line that can produce two terminals of the combiner to one same side. Attach two coaxial tubes to these output terminals. These outer conductor and inner conductor shall be shorted by the short-circuit plates 10_1 and 10_2. These two short-circuit plates are held by the connecting plate 12 through groves made in the both coaxial tubes. There is female screw pitch 13 on the connecting plate. The screwed pole 14 into female screw pitch 13 shall moves forward and backward connecting plate that positions shall short the both coaxial tubes. The rotation torque of the screwed pole 14 shall be given by the motor 15. Besides, the rotor terminal 17_3 of the variable resister 17 is mechanically connected with connecting plate 12 through connecting mechanism 16 that its position shall be moved in conjunction with positions of the coaxial tubes 9_1 and 9_2. Supplies appropriate DC or AC voltages to the fixed terminals 17_1 and 17_2 of the variable resister, the voltage of the rotor of variable resister 17_3 shall be activated as above due to the response of 1:1 to the positions of the short-circuit plates of the coaxial tubes.

The operating theory of practical operation example is also confirmed by the Fig. 3. The input reference reactance X of the shorted coaxial tubes 9_1 and 9_2 meets to the formula (2) shall be length l of reference point and position of the short circuit that is indicated by following formula

$$X = \tan (2 \pi l / \lambda) = \tan (\omega l / Vc) \ldots\ldots\ldots\ldots (4)$$

λ is wave length of signal. Vc is speed of the light. Insert this referenced reactance X into formula (3) that phase can be obtained, and the variation range of the referenced reactance X by the changes of the length l will be from - ∞ to + ∞ that can make 360 degree phase easily. For example at phase shift as 90 degree, the value of (l / λ) may 0.125.

[Effect of the Invention]

The features of this invention will be as follows.

1. Low V.S.W.R. at input. The line stretcher type is higher than 1.5, but this invention will be within 1.1.
2. Low insertion loss. The varactor diode type will loose 0.6~0.7dB of insertion loss even within Maximum phase shift 40 degree due to loss of the diode. The insertion

loss of phase shifter of this invention will be less than 0.3 dB even phase shift bigger than 90 degree.

3. Large phase shift. Maximum 40 degree at one stage in case of varactor diode method.

There is no limit of phase shift under this invention. (Extend length of short connecting lines.)

4. Small size and light weight. One stage shall be done when phase shit is larger than some volume that makes smaller size compared with varactor diode type. Also, total length at line stretcher will be two times bigger of effective movement that this invention is smaller.

The variable phase shifter under this invention has above features. Therefore, applications to the various mobile satellite communications can be expected that communications desire down sizing and light weight of systems.

[Simple Explanation of the Drawings]

[Fig. 1] is explaining mechanical drawing of the current phase shifter using U type line stretcher.

[Fig. 2] is showing diagram of the phase shifter using varactor diodes.

[Fig. 3] is showing explanation of the equivalent circuit.

[Fig. 4] is showing mechanical drawing of the variable phase shifter under this invention.

1: Input Terminal.
2: Output Terminal
3_1 & 4_1: Input & Output Outer Conductors of Coaxial Tubes.
3_2 & 4_2: Inner Conductors of Coaxial Tubes.
5_1 & 5_2: Outer Conductor and Inner Conductor of U type Line Stretcher.
6: Branch Line type 3dB Hybrid Circuit.
6_1, 6_2, 6_3 and 6_4 are: Its terminals.
7_1 & 7_2: Varactor Diodes.
8: 3dB Distribution Coupling type Hybrid Circuit.
9_1 & 9_2: Coaxial Tubes.
10_1 & 10_2: Short Contacting Plates.
11_1 & 11_2: Groves
12: Connecting Plate
13: Female Screw
14: Screwed Pole
15: Motor
16: Mechanical Connecting Structure
17: Variable Resister

17_1 & 17_2: Fixed Terminal of Variable Resister
173: Rotor of the Variable Resister.

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